AIR WAR COLLEGE

RESEARCH REPORT

THE SPACE SHUTTLE VERSES EXPENDABLE LAUNCH VEHICLES LESSONS FOR THE FUTURE?

COLONEL ROBERT M. MIHARA

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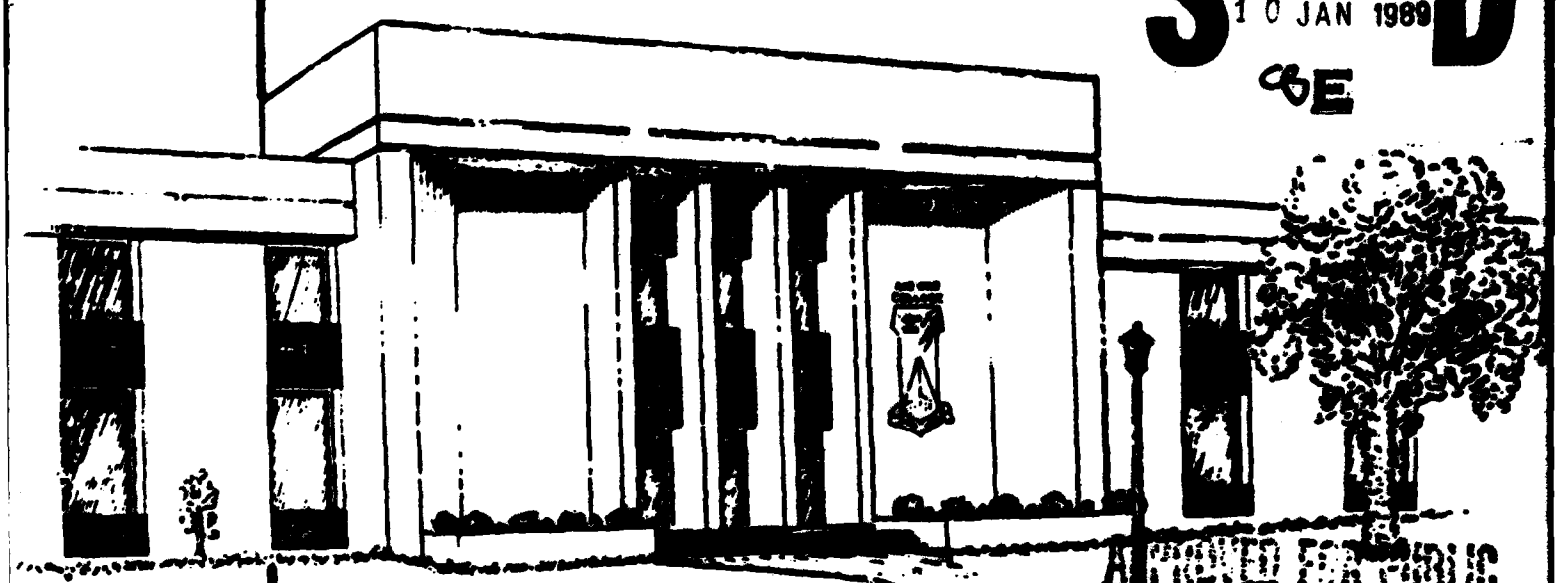

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The Space Shuttle Verses Expendable Launch Vehicles Lessons for the Future?

by
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A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE RESEARCH REQUIREMENT

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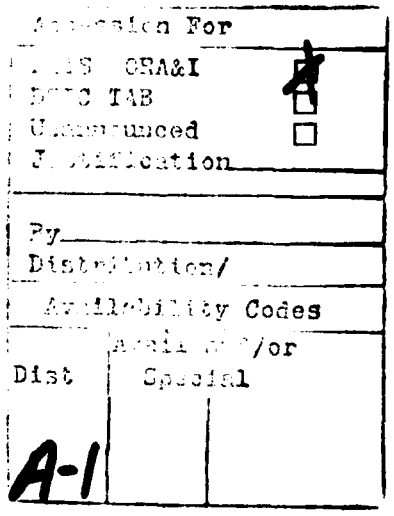

AIR WAR COLLEGE RESEARCH REPORT ABSTRACT

TITLE: The Space Shuttle Verses Expendable Launch Vehicles. Lessons for the future?

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During the development of the space shuttle, the United States space launch strategy changed from a mix of Expendable Launch Vehicles (ELVs) and shuttles to depending exclusively of the shuttle. And, for awhile the strategy seemed to be working. Then, in January 1986, on the system's 25th launch, the space shuttle Challenger exploded during takeoff and the flaw in strategy was painfully obvious to everyone. Any significant problem with the shuttle could and would ground it until the problem was corrected. A process that could take years. In the meantime, the nation would be without a launch capability. The space community lost no time in returning to a mix of ELVs and shuttles strategy.

Looking to the future, the National Aerospace Plane or the Heavy Lift Vehicle will give the nation another chance to debate what its national space launch strategy should be. This report explores the decision making process which led up to this shuttle only launch strategy to see if there are any lessons to be learned for this upcoming debate.

BIOGRAPHICAL SKETCH

Colonel Robert M. Mihara (M.S., University of Tennessee) has been working space related fields since 1975. He has served as a space research and technology development engineer, space hardware development engineer, and a space systems engineer. Colonel Mihara is a graduate of the Air War College, class of 1988.

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CHAPTER I

INTRODUCTION

During the development of the space shuttle, the United States space launch strategy changed from a mix of Expendable Launch Vehicles (ELVs) and shuttles to depending exclusively on the shuttle. And, for awhile the strategy seemed to be working. Then, in January 1986, on the system's 25th launch, the space shuttle Challenger exploded during takeoff and the flaw in strategy was painfully obvious to everyone. Any significant problem with the shuttle could and would ground it until the problem was corrected. A process that could and did take years. In the meantime, the nation would be without a launch capability. Realizing that having only a single launch system left the nation vulnerable to a single launch failure, the space community lost no time in returning to a mix of ELVs and shuttles strategy.

Looking to the future, the National Aerospace Plane (NASP) will give the nation another chance to debate what its national space launch strategy should be. This report explores the decision making process which led up to this shuttle only launch strategy to see if there are any lessons to be learned for this upcoming debate.

There is little national debate over the potential military and commercial importance of space. In fact some

visionaries believe that space is both a leverage point for the current military competition between the Soviet Union and the United States and the point from which an alternative security order can be built. (1:91) Some have gone so far as to state, "effective control of outer space means effective control of the planet." (1:113)

If space is so important, one would expect that our national launch strategy would be debated in the context of the best way to satisfy our overall national space policy. Logic and careful reasoning would be the decision makers tools. In fact, the opposite appears to be true. I feel that one key man, Dr. Hans Mark, first as Undersecretary of the Air Force for Space Systems and later as Secretary of the Air Force had his own vision of Air Force's role in space and how it should relate to NASA; and, that he drove our national launch strategy according to his particular vision using national policy as a tool to bring his vision to fruition. To a great extent, the shuttle only launch strategy was the product of this man and his interactions with his peers. His personal vision as much as logic drove the decision making process. As an institution, the Air Force did not have the tools to develop and convince him that an alternative strategy was the correct course of action.

CHAPTER II

Titan ELV

Before going further, I want to review the heritage and the operational flight history of the Titan ELV, the principle ELV alternative to the shuttle. This is important because I wish to show that the Titan ELV was and is a highly reliable, evolutionary launch system that can compete with the shuttle on both terms of performance and cost.

The giant Titan IV, formally called the Complementary Expendable Launch Vehicle (CELV) and the Titan 34D7, is the twelfth generation of the Titan family. The first generation Titan, the Titan I, was a ballistic missile and was introduced in 1959 and was followed in 1962 with the Titan II. The third generation of this family was used in 1965 to support the Gemini program. In 1964 the ballistic missile was re-engineered into a true launch vehicle with the introduction of the Titan IIIA followed by the Titan IIIB in 1966. A total of 55 Titan IIIB's were launched from 1966 to 1982. Of these 55 launches, there was only one failure, that in early 1967. At its peak in 1968 eight Titan IIIB's were launched in one year! By adding a pair of solid rocket boosters on each side of the core vehicle, the Titan IIIB was ungraded to the IIIC configuration in 1965. From 1967 to 1982, 29 Titan IIIC's were launched with 2 failures; one in

1975 and one in 1978. In 1971, another dual solid configuration, the Titan IIID started operation. From 1971 to 1982 a total of 22 Titan IIID's were launched without one failure. This perfect record was matched by the 7 Titan IIIE's launched from 1974 to 1977.

While the Titan III family was going strong, a major upgrade was made and the Titan 34B was born. From 1975 to 1987, thirteen Titan 34B's were launched and not one failed. This was very impressive for a block change bird. In 1982 the Titan 34D's started operation. In 1985, after seven successful launches, a Titan 34D failed to achieve orbit. The solids and first stage burned nominally but something happened to the second stage and the second stage and the payload had to be destroyed. After 6 years of flawless operation, a failure. Of course by this time the decision to go to a shuttle only launch strategy had long been made and the ELV's were a dying breed. This gloomy attitude seemed to be reinforced when the Titan 34D launched following the Challenger disaster resulted in a spectacular explosion over the launch pad. Two failures in a row had never happened to the Titan family before. (7:4 & 25) This seeming jinx was finally broken in October 1987 when a Titan 34D was successfully launched from Vandenberg Air Force Base, California. (2:4)

Taking all of the Titan launches from the first IIIB in 1966 through the recovery flight in 1987, a total of 136 launches were made with 131 successes and 5 failures. Thus the Titan III family reliability is 96.3% even counting the back to back Titan 34D failures. I think that these figures do show that the Titan III vehicle is the most reliable operational launch system in existence.

It was against this technical background that decision makers decided to go with the Shuttle as this nation's exclusive launch system.

If reliability wasn't the driving factor, what about performance? Could it be that the decision makers thought that the Titan III family didn't have the necessary performance to do the mission that the shuttle was programmed to do?

While the shuttle was being developed, the Titan III's were the heavy lift work horses. However, as good as they were, they did not have the lift capacity of the shuttle. Consider a launch of a Titan III from the East Coast versus a shuttle launched from the same location. Using a Transtage, a Titan III could lift a 4,200 pound, 9.3 foot in diameter, 47 foot long payload to geosynchronous orbit or 27,500 pounds to low earth orbit. (7:5) On the other hand, the shuttle could lift a 5,000 pound, 15 foot in diameter, 60 foot long

payload to geosynchronous orbit with an inertial upper stage or from 51,000 to 65,000 pounds to low earth orbit depending on the thrust of the main engines. (7:8) In should be noted that the shuttle's main engines are unique in that they can be throttled during launch to give from 100% to 109% of rated thrust. ELV's don't have this feature. Thus the shuttle has a large weight advantage over the Titan III's especially to low earth orbit.

This performance shortfall is one of the main reasons why the Air Force became interested in the Titan 34D7 as the CELV. The most powerful of the Titan III family used 5 1/2 segment solid fuel boosters. By going to 7 1/2 segments, the performance of the Titan could be improved so that it could lift a 10,000 pound, 15 foot in diameter, 67 foot long payload into geosynchronous orbit or 32,000 pounds to low earth orbit. Although less performance than the shuttle to low earth orbit, the Titan 34D7, later renamed the Titan IV, could lift the existing Air Force payloads into their required orbit. (7:8) Thus from a performance point of view, the Titan III was not a shuttle alternative for the biggest, heaviest payloads but the Titan IV was.

Now while the shuttle was being developed, the Titan III's existed but the Titan IV's were just a paper design. The question has to be whether it could be produced in a

timely manner. While the Air Force and it's prime contractor, Martin Marietta, has always maintained that such a development would be quick and relatively inexpensive, the proof is in the doing. The Air Force managed to get Martin Authority To Proceed (ATP) on the Titan IV development on 28 February 1985 and, in spite of some erratic funding, has been holding to an Initial Launch Capability (ILC) of October 1988, less than 4 years from ATP to ILC. This ILC is for the Inertial Upper Stage version of the Titan IV. While ILC has yet to be achieved, system preliminary design review and the system critical design review were both held successfully and on schedule. In addition, in 1987 two successful static firings were made. Following the Inertial Upper Stage ILC, a No Upper Stage ILC is scheduled for January 1989 followed by the Centaur ILC in March 1990. With the Centaur ILC, the Titan IV will be at full launch capability. (7:10) Looking at the development schedules, my professional opinion is that the modification to the launch complex 41 at the Eastern Test Range is the critical path to ILC. If this is the case, then the ILC will be delayed a maximum of 3 months or so to complete complex refurbishment and modifications. Therefore, I believe that the Air Force's claim that the Titan IV could be developed quickly will be proven true.

What is the possibility that the development will run into serious technical trouble? I believe that this risk is fairly low and definitely manageable. When the Titan III's were developed, Martin Marietta was the prime contractor but it had several associate contractors like Aerojet who were building the liquid rocket motors. From a management direction standpoint, associate contractors are on an equal footing. If there is a disagreement between two associates, the Air Force has to mediate. For the Titan IV development, the contractual arrangements were modified to make Martin a single prime contractor will eight major subcontractors. Martin is clearly in charge and responsible. The only remaining associate contractor is Boeing who makes the Inertial Upper Stage. In addition, the Titan IV is an evolutionary development of the Titan III family so the development risk should be minimal. All and all, I believe that this development has an excellent chance of staying close to its original schedule.

Could it be that the Titan IV's would be more expensive than the shuttle? That could be possible since the shuttle has been billed as the way to take the astronomical cost out of astronomical exploration. Unfortunately it doesn't appear to be true. In testimony to Congress, the Defense Department estimated the total direct and indirect cost in constant 85

dollars at about $114 million per flight for the shuttle (excluding other possible general overhead costs paid for by NASA) and about $112 million per flight for the Titan IV's. (4:2) I should note that the Department of Defense also estimated the cost of roughly $30 million per flight for a modified Titan II which has about one fourth the payload carrying capacity of a shuttle. I'll come back to this point latter. Thus, the cost per flight for a Titan IV is essentially the same as for a flight on the shuttle. The shuttle has no inherent marginal cost advantage over a Titan IV for large payloads.

What about for small payloads? Does the shuttle make sense? For a small military payload, using an entire shuttle flight does not make good sense. Now it is possible to launch multiple payloads with one shuttle flight. The problem is that all of these payloads have to go into similar orbits. The chances of being able to manifest multiple payloads from different groups to the same orbit is relatively small. Also the number of meaningful secondary payloads and experiments is small. Therefore, sooner or later, the small payload program offices will be faced with the necessity of buying an entire shuttle flight only to use a relatively small part of its capability. The answer to this problem is to have an inexpensive way of getting small

payloads into orbit. This is exactly what the Air Force is doing with the Titan II refurbishment. The Titan II booster will be made from retired Titan II ICBMs. The Titan II ICBM guidance, airframe and engines will be used on the refurbished Titan II booster. The payload fairing, forward skirt, attitude control system and electrical and ordnance system will be adapted from the Titan III designs. (7:20) Thus all of the high failure items on the ICBM will have been replaced with proven Titan III components.

On January of 1986 the Air Force gave Martin Marietta ATP to refurbish eight Titan II ICBMs into boosters with a priced contract option for five more. Included was the development of the services needed to launch three boosters per year and the launch complex refurbishments needed to launch these boosters from Vandenberg Air Force Base, California. The initial customers were the Defense Meteorological Satellite Program, the Navy Remote Ocean Sensing System and one of the national systems. (7:19) These customers would get the benefit of the low launch price and the operational flexibility of being able to control the timing of their launch based on their needs rather than the shuttle's schedule.

Thus at the time that the decision was made to go to the

shuttle as the national launch system, these facts were available:

A. The Titan IV could lift the same payloads into orbit as the shuttle.

B. The Titan IV was an evolutionary development of the Titan III family, the most reliable launcher available.

C. The Titan IV could be developed quicker than the shuttle.

D. In reality, the cost per flight for the Titan IV was essentially the same as that of a shuttle. This last point, however, is the result of 20/20 hindsight. As I will relate later in this report, NASA had some other cost data which led them to believe that the cost per flight for the shuttle would be very low. It is now clear that this belief was false and that the data used in coming up with the lower per flight cost estimates were obviously and grossly optimistic. a classic case of someone drinking his own bath water. NASA, however, was between a rock and a hard place. If the shuttle didn't have a cost advantage, the shuttle

couldn't be justified. If the shuttle couldn't be justified, than NASA didn't have a reason for being.

E. Small payloads could be launched more efficiently by small ELVs.

CHAPTER III

THE BEGINNING

If all of this information in favor of having at least a mix of ELVs and shuttles was available, why did we as a nation decide to go to a shuttle only national launch strategy? I believe that part of the answer comes from the way the program was originally conceived.

In 1957 the Soviets stunned the United States by orbiting Sputnik. They followed up this historic first in space by sending Yuri Gagarin into orbit a year before the United States was able to send John Glenn on his flight. If it weren't for these events, the entire history of spaceflight might have taken a different turn. The military had been slowly developing a manned spaceflight capability with the Bell X-15 rocketplane. This rocketplane was flown at Edwards Air Force Base, California. It did not take off from a runway but was carried aloft under the wing of a bomber. Released a high altitude, the rocketplane would

shoot up to the very boundary between air and space. It got so high that the X-15 needed small thrusters to control its attitude until it returned to the atmosphere where its control surfaces could work. The logical next step would have been to develop a rocketplane that could make actual suborbital flights;i.e., actually enter space for a brief period of time, then come back to earth for a landing like a glider. Then we might have developed a rocketplane that could actually orbit the earth one or more times and land like a conventional airplane. (1:37) Add a cargo carrying capability and you are very close to the goals of the NASP program.

However, in the frantic days following Sputnik, the United States felt it had to catch up to the Soviets and surpass them. It was mandatory that we get into space as soon as possible. The slow developmental approach using a rocketplane was out and the fast approach using ICBMs to boost manned capsules into a ballistic trajectory was in. (5:38) The man was more like a Reentry Vehicle than a pilot.

Sputnik and the other Soviet space firsts had caused the leadership in the United States to take a hard look at space policy. As a result of this hard look, four reasons for developing space technology were articulated:

A. Human curiosity,

B. Scientific knowledge,

C. National prestige, and

D. National defense.

The United States policy was that space was for peaceful purposes and the benefit of all mankind. To carry out this policy, a new agency was formed, the National Aeronautics and Space Administration (NASA). NASA was to exercise control over all United States space activities except those associated with national defense which would be the responsibility of the Department of Defense. The baton for manned spaceflight had been passed from the Air Force to NASA; the military would develop weapons and national defense satellites and NASA would explore the cosmos and the earth from space. The military developed ICBMs and modified ICBMs to boost their payloads into orbit. NASA developed its own super booster, the Saturn V, to boost a manned capsule to the moon and back, project Apollo, President Kennedy's vision.

In these early days, NASA and the Defense Department enjoyed some fairly good working relationships. In fact a

number of secret military sensors were tested aboard NASA's "Explorer" series of satellites in the 1960's and 1970's. (8:126-127) Unfortunately this era of cooperation wasn't to last.

With President Kennedy's assassination, his vision seemed to die with him. President Johnson who was a leader who had supported NASA in the Senate and space activities as Vice President but didn't seem to have a continuing vision to fire the American public imagination. His attention was more directed at the Vietnam conflict. Thus it fell to President Nixon to decide what NASA's post Apollo thrust would be.

There were many ambitious projects such as going to Mars and building a space station considered. All of these projects required more money than the President wanted to spend. With the Vietnam conflict eating up funds, there wasn't enough for guns, butter and space. The one common part of all these projects seemed to be the Space Shuttle. It was essential, fairly low cost and different than what President Kennedy sought. It was in this context that in January of 1972 President Nixon announced that NASA would be given $5.5 billion over six years to build a fleet of space shuttles. Thus from the very beginning, the objective was to find something cheap but worthwhile for NASA to do. The tragic thing was that at $5.5 billion the shuttle program was

significantly underfunded. There were no programmed funds to cover cost growth and the uncosted unknowns that every development program finds.

The primary motivation for the shuttle development was the projected savings offered by a reusable space "truck." According to President Nixon, the shuttle would "take the astronomical costs out of astronautics." President Nixon believed this because of a NASA cost-effectiveness study based on 500 shuttles missions between 1979 and 1990. This study concluded that it would cost $5.2 billion to launch these mission on the shuttle and $11 billion to do these same mission using ELVs. Congress funded this program and agreed to phase out ELVs as the shuttle became operational at the end of the decade. (6:87-88) Underfunded and expected to provide savings that would never materialize, the shuttle program was destined from its birth to get into trouble.

CHAPTER IV

AIR FORCE-NASA MARRIAGE

Where was the military while this decision was being made? Almost all members of the space community were attracted to the shuttle because it promised a heavier lift capability than even the large Titan III's could provide. (8:129) However, most members of the military space community

felt that the idea of relying exclusively on the shuttle as the national launch system was a mistake. This author was one of them. In fact, I can't remember a single officer in favor of relying exclusively on the shuttle. So what happened? What happened was that the basic concept of the civilian control of the military worked.

Dr. Hans Mark, first as Under Secretary of the Air Force for Space Systems and then Secretary of the Air Force, was a complete shuttle supporter. (8:185) Relatively quickly but predictably, the shuttle development program had gotten into serious financial problems. The program needed outside support to survive. Dr Mark believed that the only way to keep the shuttle program going was to force the Air Force to embrace it. (8:185) He felt that the reason that the Air Force did not support the shuttle was that the Air Force wanted to control its own launch vehicles. The shuttle was under the management control of NASA, not the payload builders and operators. This concerned people both in the military and the civilian community. Specifically, they were worried about NASA's ability and willingness to support a launch on demand. (8:168) They felt that NASA would be more shuttle orientated than payload orientated. In response to these concerns, Dr Mark developed the concept of dedicated Air Force missions in which the Air Force was in complete

control even though NASA still owned the shuttle. (8:168) After a while, it became generally accepted that the Defense Department would always have priority over all other users whenever available launch capacity was inadequate. (4:3) However, such an open policy would have made it difficult for NASA to book any commercial payloads. Any commercial customer would be reluctant to pay $50 million or so to ride standby. To alleviate this problem, Administrator Beggs negotiated a compromise with Secretary Aldridge and the Air Force. In exchange for the Air Force being given priority, NASA would be paid at the beginning of the year for all flights that it planned to make that year. In effect, what the Air Force was doing was paying a up front fixed payment to keep the shuttle flying whether or not the Air Force actually used a flight. If the Air Force actually used a flight, then it would pay the variable costs, around $35 million. This technique covered NASA for the problem of dealing with the way that the Air Force schedules launches. The Air Force schedules launches based on the expected life of a satellite. The trouble is that by necessity the Air Force is very conservative on their life estimates. As a result, satellites almost always last longer than estimated. Therefore, they don't need to be replaced. Therefore, the number of flight required goes down. If NASA was counting on

the revenue from these flights to cover their operating expenses, they would be in trouble. The up front payment takes care of this problem.

While the up front payment took care of NASA's problem, it seemed grossly unfair to the uniformed members of the Air Force. To placate the Air Force, Administrator Beggs agreed to provide some of the communications required between the shuttle facility at Johnson Space Center and Colorado Springs drawing the Air Force and NASA even closer together and making them more interdependent.

Looking back at that time, it's hard to say if someone shouldn't have spoken out. The problem is that even though most of us felt that relying on the shuttle was a mistake, we didn't have any hard data to back up our position, just engineering and programmatic experience. What we ended up doing was holding our peace and trying to implement our guidance as best we could. In fact in time, the entire Air Force space community became committed to the Shuttle because all of our other launch options were going away. It was the Shuttle or nothing. And, since our fates now depended on the shuttle, the Air Force pushed for more and more control over the shuttle program. And, since NASA needed Air Force support to help solve its money problems with the Office of Management and Budget (OMB) and the President, the Air Force

gradually got more of a say in the shuttle program. (8:168) The shuttle only national launch strategy had evolved.

In fact, NASA Administrator Paine had always felt that the only way that the shuttle program could be sold was to make it a national launch vehicle. Administrator Paine pushed this national launch vehicle concept before it was coordinated by Secretary Seamans and the Air Force. Before he resigned, Administrator Paine allowed the Air Force to levy some specifications on NASA for the performance of the shuttle. (8:101) Programmatically this approach was probably a mistake. When you let someone give you requirements on you without making them financially responsible for these requirements, you put yourself in the position of having to satisfy potentially unlimited demands. In addition there were fears that with the military was getting more and more control of NASA and that NASA would loose its openness.

This type of concern is still being expressed. On 04 August 1982, Congressman Hollenbeck said "... I can only hope the next generation of Americans will not look back upon those of us here today as the leaders who sat in silence as America turned a noble endeavor into an interstellar war machine... The greed machine of contractors, revolving-door jobs, the endless excuses to build more military hardware now

is being applied to virgin territory. What we are talking about is not national security. What we are talking about is big bucks..." (8:218)

Not only was this shotgun marriage between NASA and the Air Force causing trouble in the Air Force and in Congress, it compounded NASA's problems also. Since the Air Force now needed the shuttle for its missions, Air Force officials were saying that delays in the shuttle program could endanger national defense. When Dr Mark left, the Secretaries that followed him did not share his total commitment to the shuttle. In fact the uniformed Air Force was able to convince its management that is should have some Titans as back up if the shuttle ran into trouble. (8:195) Under the leadership of then Undersecretary Aldridge, the Air Force put together a proposal to buy 10 CELVs to back up the shuttle. Eventually these CELVs were to provide the heart of the national launch recovery program.

The marriage between the Air Force and NASA over the shuttle was not made in heaven. It caused much pain and hard feeling on both sides and between both organizations and congress. Even worse it caused some dumb decisions to be made on how our country should structure its national launch strategy. I believe that the primary cause of these problems is the initial underfunding of the project.

CHAPTER V

NATIONAL SPACE POLICY

Where was the overall guidance during all these troubled times? If our national space policy is supposed to provide overall guidance, what role did it play?

Part of the problem can be traced back to President Eisenhower's original space policy. The concept was certainly a noble one, peaceful development and exploitation of space by NASA except for those projects related to national defense which will be done by the Department of Defense. The problem with this policy is that there is no natural dividing line between peaceful projects and those relating to national defense which would be done by the Department of Defense. The problem with this policy is that there is no natural dividing line between peaceful projects and those relating to national defense. Between NASA and the Department of Defense there was going to be overlapping missions causing overlapping programs and duplications of efforts.

This overlapping of programs and missions was not important when there was adequate funding for almost anything we wanted to do in space. Predictably, when money got tight, serious problems came up. Eventually the Air Force and NASA

would have rubbed up against each other as each tried to use the same technology to satisfy their missions. The underfunding of the shuttle program just brought the problems into sharp focus.

Since the national space policy of each administration since Eisenhower's has chosen to follow the same broad outlines, I have concluded that space policy will not resolve this particular issue. Somehow the Air Force and NASA will have to learn how to coexist. To avoid unnecessary duplication of projects and overlapping responsibilities, we must find a way to divide our responsibilities in space.

CHAPTER VI

DIVISION OF RESPONSIBILITIES

The current way which we are conducting launches is a band aid. To have the Air Force conducting Titan operations and the NASA conducting shuttle operations doesn't make good sense. The concept of having an alternative way of launching if one system goes down is excellent. The problem is that by having the NASA do one and the Air Force to the other, we are practically guaranteeing that we won't be able to shift easily between one system and the other. Already the ways that each system certifies their payloads for safety are completely different. The ways that we calculate launch

loads and environments are different. Why should we make each payload developer learn two completely different ways of doing business in order to have access to both the shuttle and the Titan launch systems? What we need is one organization that handles both systems. That way each payload developer can focus his or her energy on the differences between the launch systems and not on the differences between the way that two organizations handle their paperwork.

From my experience dealing with both launch systems, I offer the following observations:

A. Because of the need for physical and electrical security, the Air Force has stricter facility requirements.

B. NASA is an open organization and wants to stay that way. It has a hard time in dealing with Air Force security.

C. NASA is not structured to be an operational organization. It was designed to be a high technology research and development organization. It does one of a kind developments best. On the other hand, the Air Force is structured to be an operational organization.

From these observations I would propose the following:

A. NASA be given the mission of proving the

technical feasibility and initial procurement of new launch systems.

B. The Air Force be given the responsibility of procuring and operating the national launch system to include both manned and unmanned systems and all supporting facilities.

C. Both Air Force and NASA work to define the requirement for follow-on launch systems.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The lessons from the past are relatively clear:

A. Obtaining adequate program funding from the very start is essential. No amount of reprogramming makes up for an under-funded start.

B. The views of one key man can keep an entire institution from saying and doing what it believes is correct. We need to institutionalize the process of developing direction based on upper tier guidance. There needs to be some internal checks and balances.

C. The conflict between the Air Force and NASA on their roles in space are built into their space mission statements. To minimize this conflict, the Air Force should focus on operations while NASA should focus on technology development and exploration.

CHAPTER VIII

RECOMMENDATION

To avoid having the same problems again, the current roles in the development of the NASP should be changed. The Defense advanced REsearch Project Agency (DARPA) and the NASA should do the initial development and proof of the NASP concept. Once the basic technical and cost feasibility has been proven and the country has decided to make a commitment to the NASP, the Air Force should develop the operational system and operate it.

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